S-94,234

IL-10,632

DIELECTROPHORETIC CONCENTRATION OF PARTICLES UNDER ELECTROKINETIC FLOW

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The United States Government has rights in this invention pursuant to Contract No. W-7405-ENG-48 between the United States Department of Energy and the University of California for the operation of Lawrence Livermore National Laboratory.

BACKGROUND OF THE INVENTION

The present invention relates to the concentration of particles in microfluidic devices, particularly to the use of dielectrophoresis to collect or concentrate the particles, and more particularly to the use of dielectrophoresis to collect particles under the conditions of electrokinetically-driven flow.

Microfluidic devices are most useful when operating with small sample volumes. Small sample volumes result in increased reaction times and reduced reagent use which means significantly reduced costs for the multitude of tests that one desires to conduct on any given sample. Dielectrophoretic concentration of the samples is a useful method for achieving these goals. Dielectrohporesis is attractive on the microfluidic scale because the forces become significant and useful at dimensions of less than 1 mm. Electrokinetic/electroosmotic flow is also useful in these devices because it obviates the need for micropumps and microvalves.

The present invention involves the combination of dielectrophoresis (DEP) and electrokinetic/electroosmotic flow. Such combination would not normally be an obvious choice since one might think that the two electric fields and their associated double charge layers may interfere with each other. Also, dielectrophoresis collection works best in the slow boundary-layer flow normally associated with pressure-driven flow. However, by the present invention, it has been found that particles can still collect even in the more uniform flow field associated with electroosmotic flow. The 5-10 mm double charge layer associated with establishing electroosmotic flow does not interfere, or be interfered with, by the DEP field in a significant way.

SUMMARY OF THE INVENTION

It is an object of the present invention to collect particles in a microfluidic channel using dielectrophoresis.

A further object of the invention is to provide for dielectriphoretic concentration of particles under electrokinetic flow.

Another object of the invention is to use delectrophoresis to collect particles under the conditions of electrokinetically-driven flow.

Another object of the invention is to use a combination of dielectrophoresis and electrokinetic/electroosmotic flow for the collection of particles in a microfluidic device.

Another object of the invention is to provide a microfluidic device capable on dielectrophoretic concentration of particles under electrokinetic flow.

Other objects and advantages of the present inventions will become apparent from the following description and accompanying drawing. Basically the present invention involves a method and apparatus for collecting or concentrating particles in a microfluidic channel using dielectrophoresis under conditions of electrokinetically-driven flow. This is accomplished by interdigitated electrodes patterned on the inner surface of a microfluidic channel, preferable formed of glass, applying a DC voltage across the ends of the channel to initiate an electrokinetic/electroosmotic flow field, and applying an AC voltage across the interdigitated electrodes to set up a non-uniform electric field capable of trapping particles using the dielectrophortic force. The trapped particles are released upon removal of the voltage to the electrodes.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated into and form a part of the disclosure, illustrate an embodiment of the invention and, together with the description, serve to explain the principles of the invention.

Figure 1 is a schematic illustration of a microfluidic eletrokinetic flow channel with interdigitated electrodes located along the length of the channel.

Figure 2 is a greatly enlarged top view of the interdigitated electrodes of Figure 1 and AC power source therefor.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to dielectrophoretic concentration of particles under electrokinetic flow. The present invention involves a method and apparatus for collecting particles in a microfluidic channel using the combination of dielectrophoresis and electrokinetic/electroosmotic flow. Electrokinetically-driven flow is an important technique for moving fluids and sample around a

microfluidic bio-chemical assay chip, and the combination with the advantages of dielectrophoretic manipulation in this regime significantly advances this field of technology.

Figures 1 and 2 schematically illustrate an embodiment of an apparatus for carrying out the present invention, with Figure 2 being a top view of a pair of interdigitated electrodes of Figure 1. Interdigitated electrodes are patterned on the inner surface of a microfluidic channel but can be suspended within the fluid. Glass is the preferred material for the microfluidic channel because it promotes electroosmotic flow, particularly if preconditioned with sodium hydroxide. However, other materials, such as certain types of plastics may be utilized. A direct current (DC) voltage is applied across the ends of the channel to initiate the electrokinetic/electroosmotic flow field. An alternating current (AC) voltage is applied across the interdigitated electrodes to set up a non-uniform electric field capable of trapping particles using the dielectrophoretic force. Particles are swept down the channel electrokinetically and are trapped within the field established by the interdigitated electrodes. The trapped particles can be released when the voltage to the interdigitated electrodes is released. Thus, this approach enables concentration of the sample prior to testing, since dielectrophoresis effects the motion on polarizable particles within a non-uniform electric field. Positive dielectrophoresis can be used to concentrate particles in areas of high electric field gradients, and can be used to eliminate the use of centrifuging to concentrate biological samples. Negative dielectrophoresis can be used to discriminate between various types of biological particles.

Referring now to the drawings, a microfluidic device generally indicated at 10 includes at least one microfluidic channel 11, having a pair of spaced sets of

interdigitaled electrodes generally indicated at 12 patterned on the inner surface of the channel 11, which, for example, may be formed of bonded glass plates with the channel 11 formed therein as known in the art. A DC voltage supply 13 having a positive electrode 14 and a negative electrode 15 located at opposite ends of channel 11 produces a voltage across the ends of the channel 11 to initiate an electrokinetic/electroosmotic flow field indicated by arrow 16. An AC power supply 17 provides a voltage which is applied across the electrode plates 18 and 19 of interdigitated electrodes 12, as shown in Figure 2, which set up a non-uniform electric field 20 capable of trapping particles 21 using the dielectriphoretic force. Each of electrode plates 18 and 19 include projecting legs 22-23 and 24-25, with leg 22 located intermediate legs 24 and 25 and with leg 25 been located intermediate legs 22 and 23.

It has thus been shown that the present invention provides for dielectrophoretic concentration of particles under electrokinetic flow, by using at least one set of interdigitated electrodes patterned on the inner surface of a microfluidic channel. Particles swept down the channel electrokinetically are trapped within the field established by the interdigitated electrodes. Thus, the apparatus can be used to concentrate the sample prior to testing due to the combined use of dielectrophoresis and electrokinetic/electroosmotic flow. While only one microfluidic channel has be shown, the present invention can be applied to microfluidic devices having a number of channels.

While a particular embodiment has been illustrated and described to exemplify and teach the principles of the invention, such is not intended to be limiting. Modifications and changes may become apparent to those skilled in the art, and it is intended that the invention be limited only by the scope of the appended claims.